DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

May 12, 2016

The Honorable Frank G. Klotz
Administrator
National Nuclear Security Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0701

Dear Administrator Klotz:

The enclosed report documents issues with the fire suppression system (FSS) for the Plutonium Facility at Los Alamos National Laboratory. It also documents issues with non-conservative assumptions, seismic interaction vulnerabilities, and incomplete functional requirements for mitigation of post-seismic fires following a design-basis earthquake. We conclude that the FSS cannot be credited as a seismically qualified safety class control for post-seismic fires without further analysis, significant system modifications, or potential replacement. Taking our report under consideration, we request your written assessment of the FSS vulnerabilities and their impact on the facility's current and planned safety posture, within 90 days of receipt of this letter, pursuant to 42 U.S.C. § 2286b(d).

Sincerely,

Joyce L. Connery
Chairman

Enclosure

c: Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

January 29, 2016

MEMORANDUM FOR: S. A. Stokes, Technical Director

COPIES: Board Members

FROM: B. Caleca, C. March

SUBJECT: Seismic Qualification of Fire Suppression System at the Plutonium Facility, Los Alamos National Laboratory

Members of the Defense Nuclear Facilities Safety Board's (Board) staff performed an onsite review of Los Alamos National Laboratory's (LANL) Plutonium Facility (PF-4) fire suppression system (FSS) during the week of November 30, 2015. The Board's staff review team was comprised of B. Caleca and C. March. The management and operating contractor at LANL is Los Alamos National Security, LLC (LANS). The National Nuclear Security Administration (NNSA) Los Alamos Field Office (NA-LA) is responsible for contract management and oversight of operations at PF-4. The staff review team discussed its preliminary observations and concerns with senior LANS and NA-LA personnel during a formal closeout teleconference on December 16, 2015.

The staff review team identified non-conservative assumptions, seismic interaction vulnerabilities, and incomplete functional requirements for mitigation of post-seismic fires following a design-basis earthquake associated with the PF-4 FSS. Based on these observations, the staff review team concludes the FSS cannot be credited as a seismically qualified safety class control for post-seismic fires without further analysis, significant system modifications, or potentially replacement given its known vulnerabilities. LANS and DOE should consider these challenges in their decision-making for planned PF-4 facility upgrades, especially when weighed against the benefits of seismically retrofitting PF-4's active confinement ventilation system.

Background. The PF-4 Documented Safety Analysis (DSA) currently credits the FSS as a safety class, Performance Category 2 (PC-2) control [1]. Its current safety class function is the mitigation of fires caused by operational accidents, with a safety significant function to mitigate post-seismic fires. In 2010, LANS engineers identified a number of seismic deficiencies in the FSS during execution of the Seismic Analysis of Facilities and Evaluation of Risk (SAFER) program. LANS engineers initiated this program to deal with a calculated increase in the seismic hazard at LANL, as presented in the 2007 update of the site's probabilistic seismic hazard analysis. Based on the SAFER results, and documented as part of the Department of Energy's (DOE) Implementation Plan for Recommendation 2009-2, *Los Alamos National Laboratory Plutonium Facility Seismic Safety* [2], DOE committed to upgrading the FSS's seismic performance to PC-3 and crediting the FSS as a safety class control for post-seismic fires at PF-4.

As part of DOE's commitment to the Board to improve the safety posture of PF-4, LANS has performed seismic analyses and retrofits both to the FSS and to the laboratory ceilings, which are required to remain in position after a seismic event for proper activation of the FSS. LANS has communicated to the Board's staff that it has completed its planned seismic upgrades of the FSS piping system, and expects to make corresponding changes in updates to the PF-4 DSA as soon as practicable. Fire protection improvements and active confinement ventilation improvements are among a number of potential upgrades that DOE is considering as part of Phase III of the Technical Area 55 (TA-55) Reinvestment Project (TRP). Both LANS and DOE engineers informed the Board's staff that budget constraints make ventilation improvements previously planned to help address Recommendation 2009-2 less attractive compared to completing fire suppression improvements and showing that revised dose consequence calculations that credit the mitigative effects of post-seismic fire suppression are sufficiently below the Evaluation Guideline. At present, however, DOE has not yet made a final decision on the scope of TRP Phase III, and LANS has not generated completed dose consequence estimates comparing the mitigative effects of fire suppression and active confinement ventilation.

Positive Observations Noted by the Staff Review Team. The Board's staff review team observed a number of improvements in PF-4's FSS and its handling of fire risks. Most notably, PF-4 fire protection and facility personnel have greatly reduced the large amounts of combustible materials previously located in staging areas, which the Board's staff had identified in earlier reviews. Removal of this material, most of which was stored in the basement, has greatly reduced the PF-4 combustible load. Other actions, such as anchoring combustible materials cabinets and instituting prohibitions on flammable materials within PF-4, also have improved the fire safety posture in PF-4.

The staff review team walked down many of the seismic upgrades performed to anchor safety-related components. Facility engineers explained their improved inspection methods for systems and components in hard-to-reach areas of PF-4 and their use of checklists tied to as-built drawings to document inspection results for the large numbers of components and anchorages. Systematic documentation of inspections tied directly to as-built drawings is a good engineering practice and should be encouraged, especially in areas such as piping and ductwork, where there are hundreds, if not thousands, of locations to inspect periodically for degradation.

Staff Safety Concerns Regarding the Fire Suppression System. During walkdowns of the facility and in discussions with LANS and NA-LA personnel, members of the staff review team made a number of observations regarding the current safety posture of PF-4 for post-seismic fires. Of these, the staff review team believes the issues listed below are a concern both for the current and future seismic safety posture of the facility:

- Seismic interaction hazards that exist between seismically qualified structures, systems, and components (SSCs) and SSCs with lower seismic performance requirements,

- FSS seismic analysis assumptions regarding the use of steel pipe fittings instead of cast or malleable iron fittings,

- Configuration changes made to the PF-4 laboratory ceilings after they were upgraded for higher seismic performance,

- Incomplete in-service-inspections (ISIs) due to a need for confined-space permits for inspections of significant portions of the FSS and a decision to forego inspections rather than obtain the permits,

- An acknowledged vulnerability in the safety class firewater loop (the inclusion of flow paths to non-safety-related facilities) that has no engineered resolution and will rely indefinitely on a compensatory measure involving operator actions during an emergency, and

- Incomplete estimates of post-seismic FSS hydraulic demands.

The staff review team believes that each of these items, on its own, would be sufficient cause for action by NA-LA and LANS due to its deleterious effect on PF-4 safety. However, considering the number of these issues, the staff review team concludes that the current condition of the PF-4 FSS does not support crediting it to perform safety functions for a fire following a PC-3 seismic event at this time.

Seismic Interaction Issues—As part of the SAFER project, LANS performed a number of facility walkdowns to identify areas where seismically qualified and non-seismic SSCs may interact, such as the impact of falling equipment on safety systems. These interactions were documented following two nuclear industry methodologies, the Seismic Qualification and Utility Group (SQUG) methodology documented in DOE/EH-0545, *Seismic Evaluation Procedure for Equipment in U.S. Department of Energy Facilities* [3], and Electric Power Research Institute-6041 (EPRI-6041), *A Methodology for Assessment of Nuclear Power Plant Design Margin* [4]. Qualified personnel performed initial qualitative screening during walkdowns, as documented in Seismic Equipment Walkdown Sheet (SEWS) forms in 2010.

During the November 30, 2015, walkdowns, the staff review team found that a number of the seismic interaction concerns identified by LANS in 2010 still existed [5]. Most notably, large air handlers were installed above fire suppression piping without adequate seismic anchorage and bracing (Figure 1). Damage to the fire suppression piping from falling equipment, such as these air handlers, would lead to a loss of water and hydraulic pressure in the facility, impairing its function after a seismic event. The site's structural engineers could not provide the staff review team with a technical justification for why this condition does not pose a seismic interaction concern. They acknowledged that not all seismic interaction effects have been dispositioned for the FSS.

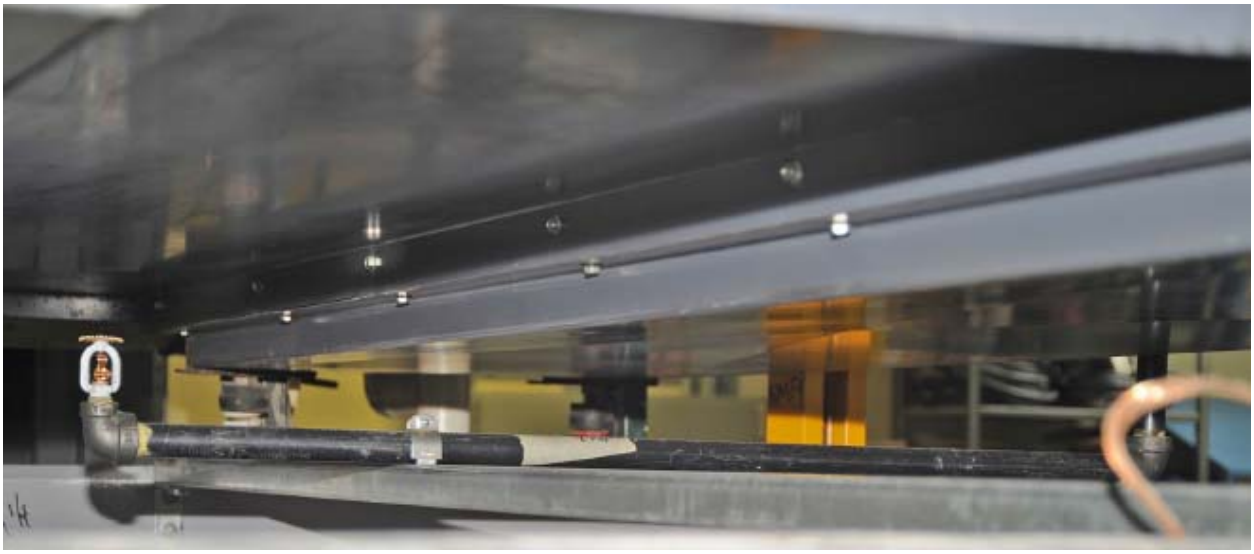

Figure 1: Example of fire suppression piping underneath unsecured equipment.

Additionally, the staff review team noted fire suppression piping supported by non-safety ductwork in several locations. During discussions with site structural engineers, the staff review team asked if these ducts had been evaluated for the FSS's seismic demands, or if SEWS forms had made assumptions about other systems, such as ductwork, being adequately designed. After a review of the SEWS forms, the staff review team noted that these instances were documented at the time as not being a seismic interaction concern by assuming the support of the ductwork was adequate. These areas of ductwork are not seismically qualified and may fail during a design basis event, damaging FSS piping that would lead to a loss of sprinkler coverage and FSS water leakage.

The Project Execution Strategy (PES) for TA-55 currently estimates completion of walkdowns to identify seismic interaction concerns in July 2016; however, there is no schedule associated with the disposition of any identified seismic interactions that may impair fire suppression function after a seismic event. The staff review team is concerned that not including a schedule to resolve these issues may delay and complicate crediting the FSS for post-seismic fires at PF-4.

Fire Suppression Seismic Analysis Assumptions—The seismic upgrades of the FSS have been qualified through the use of finite element analyses to confirm that the upgraded bracing configuration prevents any overstress of FSS piping. One of the assumptions made in the analysis was that all components of the piping have the properties of the pipe material used in the facility, grade A53 steel. The staff review team first questioned this assumption in 2012, because the use of cast-iron fittings is common in facilities of PF-4's age. Since cast-iron fittings have a significantly lower allowable stress and are prone to brittle fractures rather than more ductile failures, they are typically treated as seismic qualification outliers requiring either replacement or additional analysis to confirm that they are in low stress regions of a piping system.

Both the SQUG and EPRI seismic screening procedures provide commentary on the qualification of cast-iron piping components. DOE/EH-0545 states that "cast iron or brittle elements in a ductile piping system are outliers, but they may be accepted…if proven to be located in low seismic stress areas…" [3]. EPRI-6041 more generally states that "the use of cast iron pipe is a potential problem since it does not have the strength or ductility of steel, and usually has low capacity connections" [4].

LANL fire protection engineers confirmed to the Board's staff review team that construction submittal documents dating to the construction of PF-4 showed the use of either cast or malleable iron fittings rather than steel fittings. Malleable iron, while not as strong as steel, is a more ductile material and could potentially be qualified through analysis alone. Both the staff review team and LANL fire protection personnel agreed that at the time of construction, cast iron fittings were more common than malleable iron fittings. LANL currently specifies that incidental repairs and new FSS pipe construction use malleable iron fittings, but most of the PF-4 FSS piping has not been modified since its original construction. Physical testing would be needed to identify whether installed fittings were cast or malleable iron.

LANL structural engineers informed the Board's staff review team that they agreed that, with the current engineering calculations, this information could invalidate the assumptions of the current FSS piping analysis. The Board's staff review team believes that revising the calculations to use allowable stresses for cast iron would significantly decrease the seismic capacity of the FSS, potentially challenging even its current PC-2 seismic designation. This seismic vulnerability may be a considerable challenge for LANS to remediate in a timely fashion, given that thousands of these fittings are installed in PF-4. At the time of this report, LANS has declared a Potential Inadequacy in the Safety Analysis (PISA) specific to this staff concern.

Configuration Changes to Laboratory Ceilings—During walkdowns of PF-4, the staff review team viewed one of the laboratory ceiling spaces where LANS has made fire suppression and structural upgrades to the roof girders. Damage or collapse of parts of the laboratory ceiling during an earthquake may damage fire suppression piping and prevent the proper heat activation of sprinkler heads during a post-seismic fire. The staff review team noted that LANS installed significant metal decking that is supported by the laboratory ceiling (Figure 2). This differs from the facility configuration assumed in the seismic evaluation performed in 2011 by LANS's subcontractor [6]. Facility engineers told the staff reviewers that these changes are intended to be permanent.

When asked if this significant increase in dead load and seismic mass added to the laboratory ceilings had been accounted for, LANL staff engineers said that they had not updated this calculation with the configuration changes made since 2011, but believed the added decking would not exceed the dead load assumptions used in the calculations. In further discussions, LANS engineers estimated that the metal decking mass will not challenge the assumed miscellaneous loads on the laboratory ceiling. This condition was not formally evaluated before installation of the decking, and is a lapse in configuration management of the laboratory ceiling. The *Nuclear Safety Management* Rule (10 CFR Part 830) requires evaluating the impacts of configuration changes on safety-related SSCs before they are made [7]. Consistent with the rule, the staff believes that unanalyzed conditions, such as the metal decking, should have been evaluated through the LANS Unreviewed Safety Question process.

Figure 2: Condition of laboratory ceiling as evaluated (top) and current configuration (bottom).

Fire Suppression System In-Service Inspections—Facility engineers noted that significant portions of the fire suppression system had not been surveyed as part of required ISIs in cases where confined space permits were required for access. LANS procedures allow an exemption for inaccessible spaces, and these areas had been considered inaccessible. This included the service chase above the first floor corridors that allows access to much of the piping above laboratory ceilings. Considering how much of the critical piping is located in these areas, LANL should reevaluate its implementation of these procedures to provide more complete ISI coverage in the future. In subsequent discussions, the facility fire protection engineer said that future ISI procedures will include viewing piping accessible from the service chase. The staff review team believes this is a positive development at PF-4.

Emergency Procedures for Isolation of Non-Safety Structures—Currently, the normal FSS underground piping alignment allows the east fire pump house (fed by the safety class water supply for PF-4 fire suppression systems) to also supply non-seismically qualified fire suppression systems in nine adjacent buildings. The DSA has identified this as a vulnerability in the event of a PC-2 seismic event. If these buildings fail, FSS water flow could be diverted from PF-4. The compensatory measure cited in the current PF-4 DSA is to isolate the FSS water supply to those buildings if the underground piping is in a configuration that allows water from the west fire pump house to feed them.

LANS emergency procedures for isolation of such structures from the safety-class fire water loop require the incident commander to coordinate a number of actions, including the opening or breaking of locks, evacuating people from the buildings, and closing a number of valves, depending on the post-seismic condition of the structures. It is unclear to the Board's

staff whether first responders have been trained on these actions, or whether the actions could be readily accomplished among other required actions during a seismic event. While this vulnerability will only impair PF-4's FSS if one of the redundant pump houses fails to provide water to the system, this prevents the FSS system from meeting the single-failure criterion for a safety class system until this vulnerability is corrected.

Functional Requirements for the Fire Suppression System—The current PF-4 DSA [1] has identified a planned upgrade to the FSS:

> *Upgrade the fire suppression system seismic capacities with regard to the new site-specific seismic hazard analysis (including seismically upgrading TA-55 fire loop connection to buildings and other FSS components; this is part of the TA-55 Reinvestment Project phase 3 proposed scope).*

LANS's safety basis staff has not developed detailed information on the planned safety function, functional requirements, and performance criteria for the FSS for PC-3 seismically induced fires. Without this information, the Board's staff review team could not identify the required FSS capabilities that would be needed for fires induced by a PC-3 seismic event. As a result, clear performance criteria do not exist to address items such as:

- The number of operating sprinklers needed to suppress all potential seismically induced fires,
- The amount of potential water leakage caused by damage from seismic interactions with other equipment to include in FSS analyses,
- The minimum hydraulic performance of the system, and
- The required water supply.

The staff review team believes this information is needed to validate the scope of the upgrades required to ensure that safety class fire suppression capabilities at PF-4 will be capable of satisfactorily mitigating post-seismic fires for PC-3 events. At this time, neither the TA-55 PES nor the TRP Phase III documents address this facet of the FSS, making it unclear when these criteria would be generated and applied to the system in PF-4.

Conclusions. Based on the results of this review, additional information and analysis are needed to demonstrate that the PF-4 FSS can meet its credited safety function. Given the unresolved concerns about seismic interactions and cast iron fittings that have resulted in a PISA declaration by LANS, it is not clear that the FSS will conform to PC-2 seismic performance, as required in the currently implemented DSA. Further, more information and analysis are needed to validate the required scope of the upgrades needed for the planned improvements (i.e., PC-3) identified in the DSA. While the TA-55 PES states that fire suppression upgrades to the FSS piping are largely complete with the exception of walkdowns, the Board's staff review team does not believe the FSS improvements are complete enough to credit the FSS as a PC-3 safety class system. LANS and DOE should consider these challenges in their decision-making for planned facility upgrades to PF-4, especially when weighed against the benefits of seismically retrofitting the facility's active confinement ventilation system.

Cited References

1. Los Alamos National Laboratory, TA55-DSA-2011-R1.7, *TA-55 Documented Safety Analysis*, October 2014.

2. United States Department of Energy, *Implementation Plan for Defense Nuclear Facilities Safety Board Recommendation 2009-2*, July 2010.

3. United States Department of Energy, DOE/EH-0545, *Seismic Evaluation Procedure for Equipment in U.S. Department of Energy Facilities*, March 1997.

4. Electric Power Research Institute, EPRI-6041, *A Methodology for Assessment of Nuclear Power Plant Design Margin*, August 1991.

5. Los Alamos National Laboratory, *Seismic Equipment Walkdown Sheet Package, Fire Protection Basement Area*, July 2010.

6. CJC and Associates, CJC-PF4-003, *Bracing for PF-4 Ceiling Support Steel*, September 2011.

7. 10 CFR Part 830, *Nuclear Safety Management*, Federal Register, January 10, 2001.

Other References

1. United States Department of Energy, DOE-STD-1020-2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, January 2002.

2. Defense Nuclear Facilities Safety Board, Recommendation 2009-2, *Los Alamos National Laboratory Plutonium Facility Seismic Safety*, October 2009.

3. Los Alamos National Laboratory, TA55-DSA-2015-R0, *TA-55 Documented Safety Analysis*, May 2015.

4. Los Alamos National Laboratory, CALC-11-TA55-FPS-024-S, R0, *PF-4 Basement Fire Suppression Piping*, May 2011.

5. Los Alamos National Laboratory, CALC-11-TA55-FPS-029-S, R0, *Mezzanine Fire Suppression Piping*, June 2011.

6. Los Alamos National Laboratory, CALC-11-TA55-FPS-032-S, R0, *Fire Water Supply Tank, Piping and Fire Loop*, May 2011.

7. Los Alamos National Laboratory, CAL-13-TA55-FPS-046-M, R0, *Piping Analysis for PC-3 Seismic Upgrades to PF-4 Service Chase Fire Suppression System Piping*, February 2015.

8. Los Alamos National Laboratory, CAL-15-TA55-FPS-011-M, R0, *Resolution of Non-Installable FSS Supports on First Floor of PF-4*, February 2015.

9. Los Alamos National Laboratory, CAL-15-TA55-FPS-013-M, R0, *Piping Analysis for PC-3 Seismic Upgrades to PF-4 Basemat Fire Suppression*, February 2015.

10. Los Alamos National Laboratory, CAL-15-TA55-FPS-015-M, R0, *Piping Analysis for PC-3 Seismic Upgrades to PF-4 Mezzanine Fire Suppression*, February 2015.

11. Los Alamos National Laboratory, CAL-15-TA55-STR-012-S, R0, *Evaluation of PF-4 Ceiling Support Structure for PC-3 Seismic Loads*, February 2015.

12. Los Alamos National Laboratory, CAL-10-TA55-0004-035 Appendix XX, R0, *Seismic Evaluation of Fire Suppression Pump Houses*, September 2010.

13. Los Alamos National Laboratory, TA55-PES-11-001, R4, *TA-55 Project Execution Strategy*, December 2015